Annual Report - Microphysical Properties of Monsoon Precipitation Retrieved from Precipitation Profilers in Support of NAME (GC04-064)

PROJECT DURATION
April 2004 - March 2006 (2 Years)

ANNUAL REPORT PERIOD
April 2004 - March 2005 (submitted February 2005)

PRINCIPAL INVESTIGATORS
Dr. Christopher R. Williams[1,2] (lead)
Dr. Allen White[1,3]

CO-INVESTIGATORS
Dr. Marty Ralph[3]
Dr. Kenneth S. Gage[2]

INSTITUTIONS
[1] Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado at Boulder
[2] NOAA Aeronomy Laboratory
[3] NOAA Environmental Technology Laboratory

INTRODUCTION
This project supported the deployment of three instruments during the 2004 North American Monsoon Experiment (NAME 2004). Two radar profilers and one surface disdrometer were located near Estacion Obispo, Mexico, (see Figure 1) from late July through September 2004. Radar profilers observe the vertical structure of precipitating cloud systems and the analysis of these observations will lead to better understanding of the microphysical processes associated with warm-shallow convective rain (no ice processes), deep convective rain (with ice processes), and stratiform rain.

PROJECT GOALS
There are two goals with this project. First, the observations will be collected and initial quality control will be performed on these observations. The second goal is to calibrate the observations and make precipitation products available to the precipitation modeling community. The first goal has been achieved during the first year of this project, and the second goal will be completed during the second year of funding.

METHOD
This project provided funds to the NOAA PACS project led by Dr. Clark King to install a 2875-MHz vertically pointing precipitation profiler, a 449-MHz vertical air motion profiler, and a surface Joss-Waldvogel Disdrometer at the boundary layer/flux site located near Estacion Obispo, Mexico (24.28º N, 107.16º W) (see Figure 1). The

installation and day-to-day operations were managed by that project. After the raw profiler observations were delivered to our host laboratory, the PIs of this project began the initial quality control processing of the observations. A project web page was developed and shows all of the raw observations that were collected during the field campaign. During the second year of this project, the observations will be calibrated to produce a precipitation data set that will be beneficial to the precipitation modeling community. Preliminary analysis of the observations indicates that 23 rain events were observed during the NAME campaign and these events include both maritime and continental rain regimes. Collaborations with precipitation modelers will be established to determine precipitation value-added products beneficial to the modeling community. The quality controlled precipitation products from the 23 rain events will be available through our project web page.

RESULTS AND ACCOMPLISHMENTS

A project web page was developed and shows all of the raw observations collected during the NAME 2004 field campaign at the Estacion Obispo, Mexico, field site. This web page can be viewed from our host laboratory web page by choosing 'Precipitation Profiler Data' under the 'Data' section heading on the left side of the page. The full URLs are:

ETL/AL main NAME Page: http://www.etl.noaa.gov/programs/2004/name/
ETL/AL Precipitation Page: http://www.etl.noaa.gov/programs/2004/name/precip/

Our project web page has QuickTime animations of all of the raw observations collected from the following instruments:

2875-MHz precipitation profiler
449-MHz wind profiler (including the vertical mode)
915-MHz wind profiler
Ceilometer
Surface meteorological instruments
Surface Joss-Waldvogel Disdrometer

From the 2875-MHz precipitation profiler observations, 23 rain events have been identified. These 23 rain events will be processed individually so that, if needed, the quality control processing can be adapted to the unique features of each rain event. The 23 rain events are tabulated on the web page and the analysis performed for each rain event will be included on our web page as each rain event is studied in detail. Our project web page will contain the quality controlled precipitation products generated for each rain event. These precipitation products will also be available through a link on the NCAR JOSS NAME web page.

Figure 2 illustrates the quality of the data collected by showing the time-height cross section of 2875-MHz precipitation profiler reflectivity, mean Doppler velocity and velocity variance during the 30-31 July rain event. The reflectivity shown in the top panel shows a convective cell passing over the profiler site at 0100 UTC with stratiform rain occurring between 0200 and 0330 UTC. The mean Doppler velocity in the middle

panel shows large updrafts occurring in a convective cell while the bottom panel shows a corresponding increase in spectral variance due to the turbulent motions.

On the down side, the Joss-Waldvogel disdrometer did not function properly. The unit was less than 8 months old when it went into the field, essentially a brand new instrument. The instrument detected small and large rain drops qualitatively, but the number of raindrops in each diameter size was severely underestimated. The instrument and the data set have been sent back to the manufacturer for repair and to determine if a correction factor can be derived to correct for the under estimation of the drop count. The Joss-Waldvogel disdrometer was the only instrument that did not perform well.

Since the quality of the Joss-Waldvogel disdrometer observations is still being investigated, the S-POL reflectivity over the profiler site will be used to calibrate the 2875-MHz precipitation profiler. The Estacion Obispo profiler site was located about 45 km towards the North of the S-POL scanning radar as shown in Figure 1. Figure 3 shows the reflectivity observed by the vertically pointing 2875-MHz precipitation profiler and the S-POL scanning radar over the Estacion Obispo profiler site for one rain event. The top panel shows the profiler reflectivity in its original 60-m vertical and one minute resolution. The middle panel shows the profiler reflectivity reduced to 775-m vertical resolution to match the S-POL beamwidth over the profiler site. The bottom panel shows the S-POL reflectivity with a 5-minute duration even though the actual S-POL dwell time over the profiler site is only a fraction of a second. The simultaneous profiler and S-POL reflectivity observations were compared for this one rain event and the scatter plot is shown in Figure 4. The precipitation profiler has been calibrated by changing the profiler gain until the bias between the two data sets is zero.

Collaborations have begun with researchers at the Colorado State University in Fort Collins (Drs. Rutledge, Lang, Nesbitt, and Cifelli), at NCAR (Drs. Cohn and Brown), and within the NOAA Environmental Technology Laboratory (Drs. Fairall, Hare, and Zuidema). The CSU researchers provided the S-POL observations for the rain event shown in Figures 3 and 4. During the second year of this project, they will provide S-POL observations for all of the rain events observed over the profiler site so that the profiler calibration can be performed for each rain event. The NCAR researchers will provide the raw 915-MHz profiler observations collected at the three Integrated Sounding System (ISS) sites (Puerto Penasco, Bahia Kino, and Los Mochis). Dr. Fairall's research group will provide the 915-MHz profiler observations collected on the R/V Altair. These raw 915-MHz profiler observations will be processed in a similar manner as the Estacion Obispo precipitation profiler raw observations to reveal the vertical structure of the precipitating cloud systems throughout the coastal NAME domain.

FUTURE WORK

The 2875-MHz precipitation profiler and 449-MHz vertical air motion profiler observations collected at Estacion Obispo need to be quality controlled and the precipitation products for each of the 23 rain events need to be generated. The 449-MHz vertical air motion profiler observations will be processed to estimate the vertical air motion below the freezing level during each rain event. Figure 5 shows the observed

Doppler velocity spectra from the 2875-MHz profiler (panel *a*) (This profiler is also called a S-band profiler because of its operating frequency.) and the 449-MHz profiler (panel *b*). The Rayleigh scattering component of the Doppler spectra is similar for both instruments while the 449-MHz profiler contains a Bragg scattering signal near zero Doppler velocity. This Bragg scattering signal provides an estimate of the vertical air motion. Each profile of spectra will be processed to identify the air motion using a quasi-automatic processing routine that will require the PI to visually inspect each profile for errors in the estimation procedure. This processing is time consuming because the air motion signal is typically a couple orders of magnitude less than the precipitation signal.

While reflectivity, mean Doppler velocity, and vertical air motion below the freezing level are the initial products derived from the profiler observations, collaborations will be established that will help develop new precipitation value-added products useful for the modeling community. These proof-of-concept precipitation products will also be made available through our project web page to the modeling community.

The vertical structure of the precipitating cloud systems observed by the five profilers deployed during the NAME 2004 field campaign will be analyzed to quantify the differences in vertical structure during maritime and continental rain regimes. This analysis will lead to proof-of-concept parameterizations for stratiform rain that would be beneficial to precipitation modelers. An abstract titled "Vertical Structure of Maritime and Continental Stratiform Rain Regimes Derived from Radar Profilers during NAME 2004" has been submitted to the 5th International Scientific Conference on the Global Energy and Water Cycle which will be held in Orange County, CA, 20-24 June 2005.

PUBLICATIONS FROM THIS PROJECT

A project web site was developed and is accessible to the public. This web site contains the raw observations collected during the field campaign as well as initial analyses of the observed rain events. This web site will also contain the quality controlled precipitation products that will be made available to the modeling community as those value-added products are produced. The full URL of our project web page is: http://www.etl.noaa.gov/programs/2004/name/precip/

The data collected by the 2875-MHz precipitation profiler and 449-MHz vertical air motion profiler as well as the quality control processing procedures will be described at the NAME Data Workshop that will be held in Mexico City, MX, 9-11 March 2005.

An abstract has been submitted to the Measuring and Predicting Precipitation Theme at the 5th International Scientific Conference on the Global Energy and Water Cycle that will be held in Orange County, CA, 20-24 June 2005. The abstract is titled, "Vertical Structure of Maritime and Continental Stratiform Rain Regimes Derived from Radar Profilers during NAME 2004", by C.R. Williams, A.B. White, M.F. Ralph, K.S. Gage, J. Hare, P. Zuidema, S.A. Cohn, and W. Brown.

An abstract has been submitted to the Special GAPP PI Poster Session at the 5th International Scientific Conference on the Global Energy and Water Cycle that will be

held in Orange County, CA, 20-24 June 2005. The abstract is titled, "Precipitation Profiler Observations made at Estacion Obispo, MX, during NAME 2004", by C.R. Williams, A.B. White, M.F. Ralph, and K.S. Gage.

An abstract has been submitted to the 3rd GEWEX Cloud Systems Study (GCSS) meeting in Athens, Greece in 14-21 May 2005. The abstract is titled, "Error Statistics of DSD Estimates Derived from Radar Profilers", by C.R. Williams and K.S. Gage.

CONTACTS

Web Page: http://www.etl.noaa.gov/programs/2004/name/precip/

Dr. Christopher R. Williams
Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado at Boulder
NOAA Aeronomy Laboratory
325 Broadway, Boulder, CO 80305
E-mail: Christopher.R.Williams@noaa.gov
Phone: (303) 497-3829
Fax: (303) 497-5373

Dr. Allen B. White
Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado at Boulder
NOAA Environmental Technology Laboratory
325 Broadway, Boulder, CO 80305
E-mail: Allen.B.White@noaa.gov
Phone: (303) 497-5155
Fax: (303) 497-6101

Dr. Marty Ralph
NOAA Environmental Technology Laboratory
325 Broadway, Boulder, CO 80305
E-mail: Marty.Ralph@noaa.gov
Phone: (303) 497-7099
Fax: (303) 497-6101

Dr. Kenneth S. Gage
NOAA Aeronomy Laboratory
325 Broadway, Boulder, CO 80305
E-mail: Kenneth.S.Gage@noaa.gov
Phone: (303) 497-3964
Fax: (303) 497-5373

FIGURES

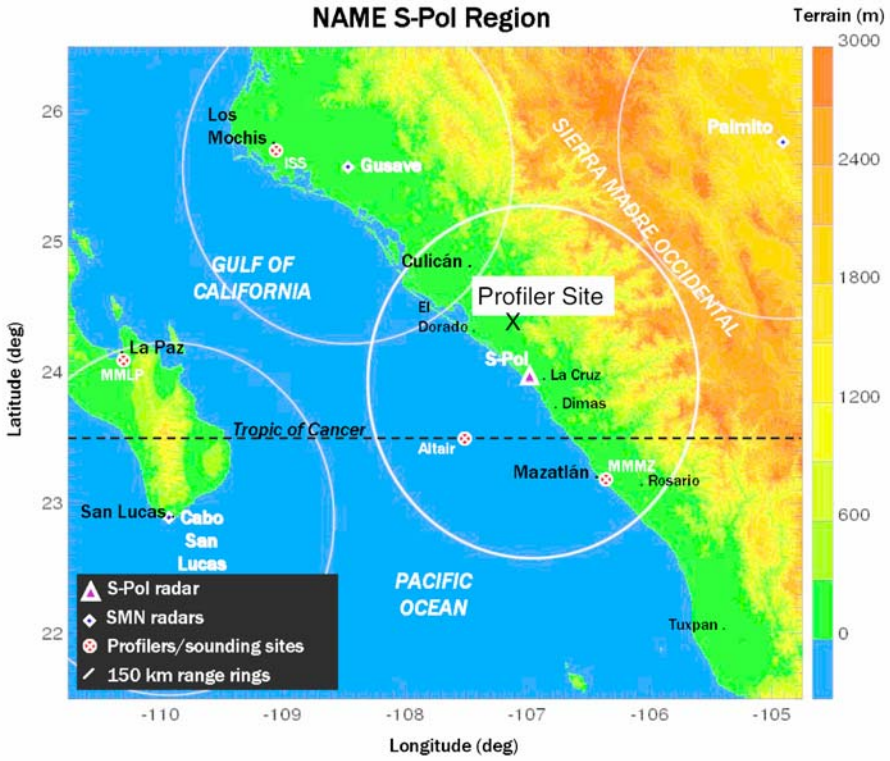

Figure 1. Map of the NAME S-POL region showing the location of the profiler site near Estacion Obispo, MX, and the spatial coverage of the S-POL scanning radar and the Gusave and Cabo San Lucas SNM scanning radars.

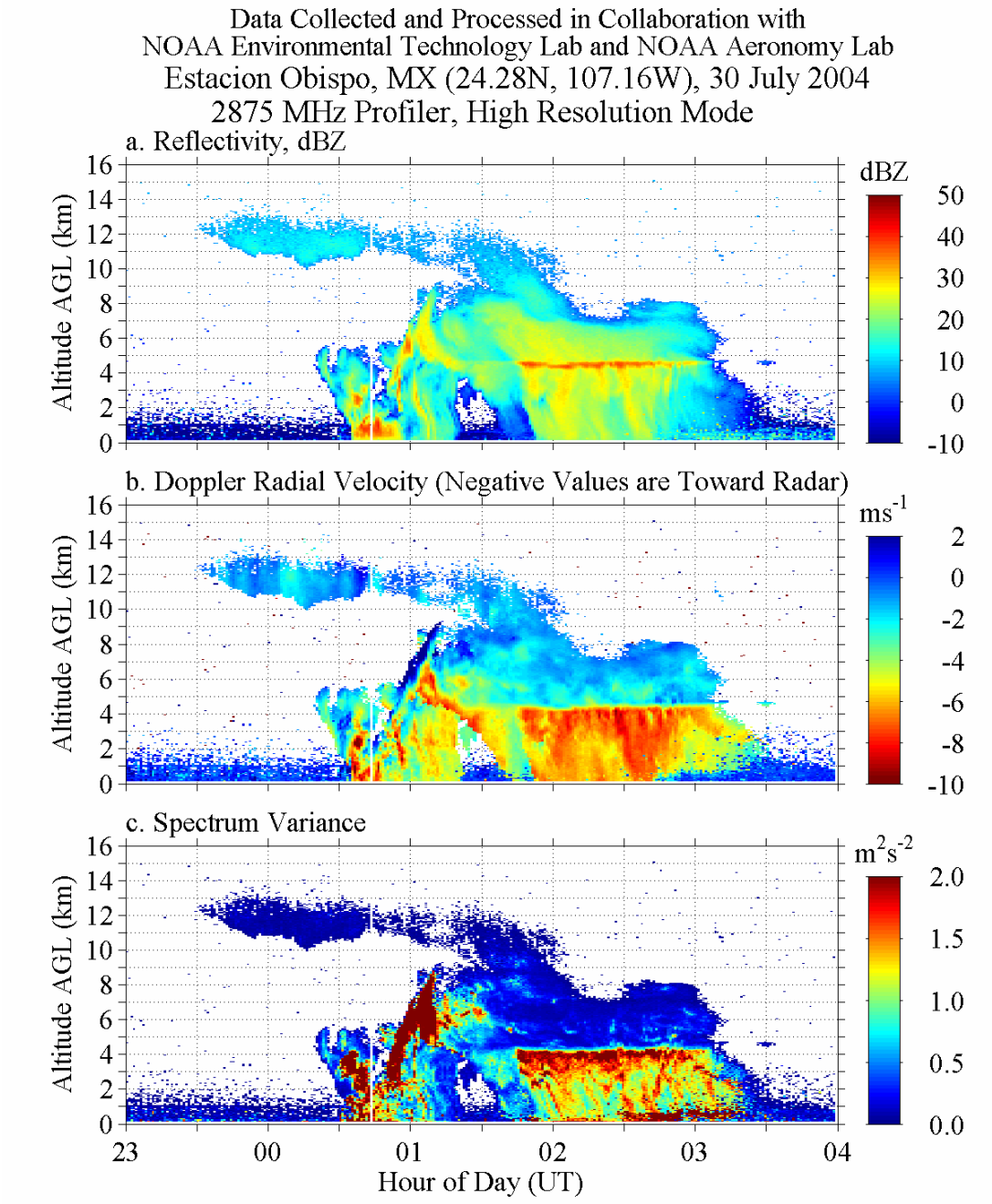

Figure 2. Time-height cross section of (a) reflectivity, (b) mean Doppler velocity, and (c) velocity spectrum variance observed by the 2875-MHz precipitation profiler during the 30-31 July 2004 rain event. The convective cell passing over the profiler at 0100 UTC is identified by the increased reflectivity above the freezing level (~4.5 km), the upward mean Doppler motion on the leading edge of the cell, and the increase spectrum variance. The stratiform rain from 0200 to 0300 UTC is identified by the well defined radar brightband and the change in mean Doppler velocity and spectrum variance as the snow and ice particles melt into raindrops.

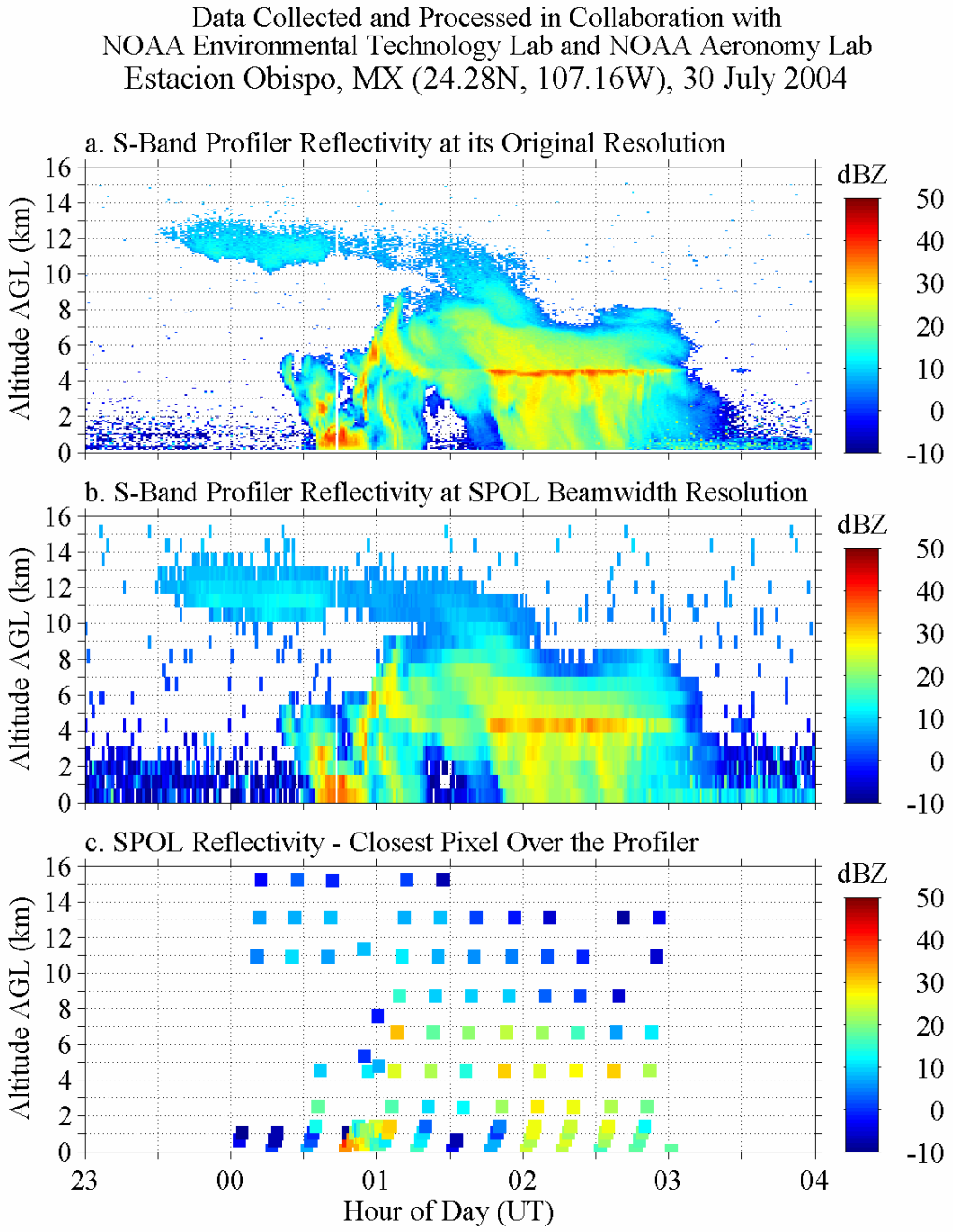

Figure 3. Time-height cross section of reflectivity observed by (a) the 2875-MHz precipitation profiler at the original 60-m vertical and one minute temporal resolution, (b) the 2875-MHz precipitation profiler averaged to 775-m vertical resolution to match the vertical resolution of the S-POL scanning radar, and (c) the S-POL scanning radar observations made over the precipitation profiler site.

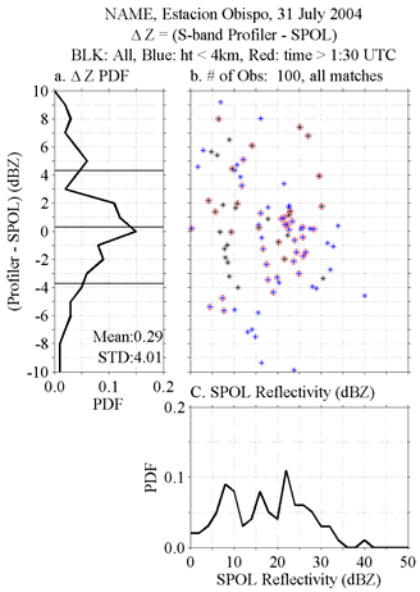

Figure 4. Reflectivity difference between the 2875-MHz precipitation profiler and the S-POL scanning radar for the simultaneous observations shown in Figure 2, (a) shows the PDF of the reflectivity difference (Profiler - S-POL), (b) shows the scatter plot of the individual sample points, and (c) shows the PDF of the S-POL reflectivity.

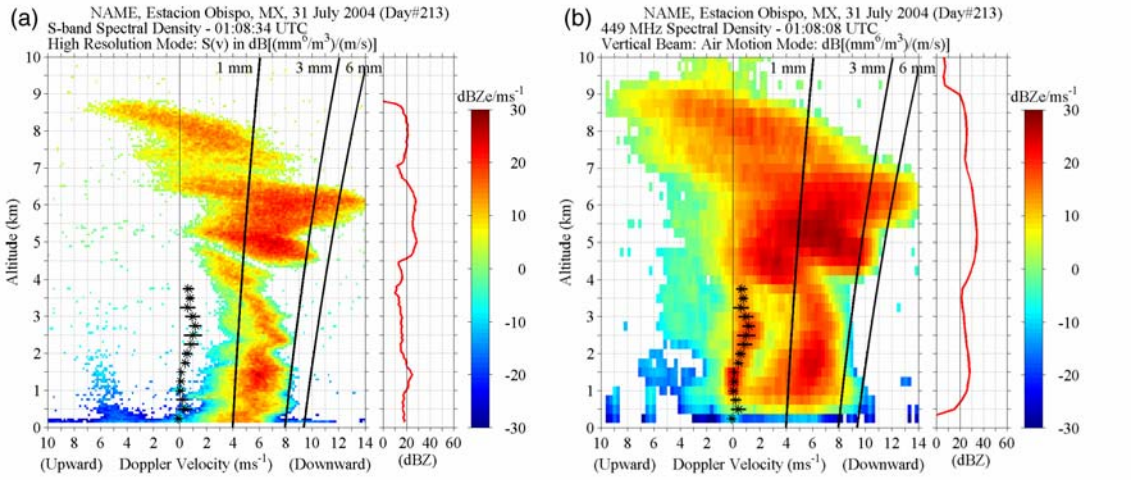

Figure 5. Vertical profiles of Doppler velocity spectral density estimates by (a) the 2875-MHz (S-band) precipitation profiler and (b) the 449-MHz vertical air motion profiler. The air motion is estimated from the Bragg scattering component in the 449-MHz profiler spectra observations and the estimate is shown with the asterisks in both panels. The panels on the right with the red line indicate the estimated total reflectivity. The 449-MHz profiler reflectivity is greater than the 2875-MHz profiler reflectivity because both the Bragg and Rayleigh scattering components contribute to the 449-MHz reflectivity estimate. The vertical lines indicate the altitude adjusted terminal fall speed of 1, 3, and 6 mm diameter raindrops.